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SPACE-TIME DISTRIBUTION OF BIVALVE LARVAE IN THE MIRA ESTUARY (PORTUGAL)

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Key Words: Bivalve larvae, Mira estuary, Portugal.

Abstract: Spatio-temporal variability of the distribution of bivalve larvae was studied in the Mira estuary, Portugal, based on plankton samples made from February 1993 to October 1993. Bivalve larvae were present in the plankton assemblage from March to the end of September, with higher values of density in April/May and July. Twenty-seven species of bivalve larvae were identified and seven species were considered abundant in this environment: *Adula simpsoni*; *Mytilus edulis*, *Ostrea edulis*, *Loripes lacteus*, *Cerastoderma edule*, *Ensis siliqua* and *Thracia distorta*. According to the curves of cumulative frequencies, only three groups of "geographical separated" species can be pointed out: *Cerastoderma edule*; *Ensis siliqua*; *Adula simpsoni* and *Thracia distorta* are considered as typically marine species. *Loripes lacteus* and *Mytilus edulis* are considered with marine affinity. *Ostrea edulis* occurred mainly in the interior of the estuary, and was the only species that clearly could be considered an estuarine species. Salinity showed to be the major barrier to larval dispersion and chlorophyll *a* showed a positive relationship with larval abundance. Results also confirmed that in southern European estuaries, bivalves will have more than one reproductive period or even, a continuous gonad output from spring to the end of summer.

Riassunto: La variabilità spazio-temporale di distribuizione delle larve dei bivalvi è stata studiata nell'estuario del Mira, in Portogallo, sulla base di prove di plancton prese dal febbraio 1993 all'ottobre 1993. Nel plancton sono state trovate larve di bivalvi da marzo alla fine di settembre, mostrando i più elevati valori di densità in aprile/maggio e luglio. Sono state identificate ventisette specie di larve di bivalvi delle quali sette specie sono state considerate abbondanti in questo ambiente: *Adula simpsoni, Mytilus edulis*, *Ostrea edulis*, *Loripes lacteus*, *Cerastoderma edule*, *Ensis siliqua* e *Thracia distorta*. In accordo con le curve di frequenza cumulativa, possono essere presi in considerazione solo tre gruppi di specie "separate geograficamente": *Cerastoderma edule, Ensis siliqua, Adula simpsoni* e *Thracia distorta* sono considerate come specie tipicamente marine, *Loripes lacteus* e *Mytilus edulis* sono considerate specie ad affinità marina. *Ostrea edulis* è stata riscontrata fondamentalmente all'interno dell'estuario ed è stata la sola specie che ha potuto essere considerata con chiarezza specie propria dell'estuario. La salinità è apparsa la maggiore barriera alla dispersione delle larve, mentre la clorofilla ha mostrato un effetto positivo sull'abbondanza delle larve. I risultati hanno anche confermato che negli estuari dell'Europa del Sud i bivalvi possono avere più di un periodo riproduttivo o perfino una produzione continua delle gonadi dalla primavera alla fine dell'estate.

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Introduction

The Mira estuary is a small tidal estuary on the southwestern coast of Portugal (Fig.1). The estuary is approximately 40 Km long, with a depth varying from 10 to 5 m in the lower end, and reaching less than 3 m at the upper limit of tidal influence. According to ANDRADE (1986), tidal penetration ranges from 2.5 Km in neap tide to 7.5 Km in spring tide. Water varies from vertically homogeneous in spring tides, occurring at new and full moons, to slightly stratified in neap tides during quarter phases of the moon. Sediment varies from medium well sorted sand at the mouth of the estuary, to mud at the upper estuary. Macrobenthic communities follow these estuarine gradients within a *continuum* (ANDRADE, 1986).

In the context of this general characterisation, the studies carried out since 1987 allowed to study larval cycles, abundance and distribution of planktonic larvae along the Mira estuary. PAULA (1989, 1993) and RÉ (1990) described crustacean and fish larval cycles in the estuary. The study of zooplankton communities showed that bivalve larvae are one of the major components of zooplankton in Mira estuary (PAULA, 1987).

As several other estuarine larvae, planktonic larvae of bivalves are under the influence of two main factors. The first being the physical and chemical gradients along an estuary, which are the cause both for the concentration of larvae within specific water masses, and different distributions along the larval stages. On the other hand, in spite of the action of tidal cycles and river flow, spreading larval stages from spawning sites, species remain aggregated within estuaries, several times with dynamic processes of retention (see BOUSFIELD, 1955; WEINSTEIN *et al.*, 1980; FORTIER & LEGGETT, 1982 and NORCROSS & SHAW, 1984 for reviews). Furthermore, as Mileikovsky (1970) stated, the study of the distribution and dynamics of larvae in the planktonic environment, shows the variability of the reproductive ecology of its benthic parental forms and contributes to the knowledge of the cycle of planktonic communities.

Present work intends to be a contribution to the knowledge of spatial and temporal distribution of bivalve larvae in a southern European estuary. Actually, this is a biogeographycal area under particular climate conditions, mixing Mediterranean and north Atlantic characteristics and species. Consequently, the pattern of occurrence and distribution of planktonic bivalve larvae will undoubtedly be the reflex of that double influence.

Methods

Sampling Methods

Bivalve larvae were sampled throughout a grid of ten stations 2 Km apart, beginning at the mouth of the estuary up to 20 Km in the upper estuary and corresponding to salinity ranging from 35 ‰ to near 0 ‰. A plankton net with circular mouth operture, 20 cm in diameter and 150 cm long was used, with a mesh of 125 µm, and equipped with a Hidrobios flowmeter. Tows were made horizontally, at a depth of nearly 1 m, for 2 min at a speed of about 2 Knots (1 m/s^{-1}). Sampling was monthly carried out with full moon both at low and high tides, from February to October 1993. Samples were fixed and preserved with buffered 5% formaldehyde. Sub-sampling was made using a Folsom plankton splitter, and the larvae were counted, measured and identified with a binocular microscope. Identification was based on published descriptions (STAFFORD, 1912; NELSON, 1928; LEBOUR, 1938; SULLIVAN, 1948; REES, 1950; ANSELL, 1962; NEWELL & NEWELL, 1963; CHANLEY, 1965, 1969; LOOSANOFF *et al.*, 1966; RANSON, 1967; SENTZ-BRACONNOT, 1968; CHANLEY & ANDREWS, 1971; PASCUAL, 1971, 1972; CAMACHO & CABELLO, 1973; GUÉRIN, 1973; LEPENNEC, 1973, 1978, 1980; SCHWEINITZ & LUTZ, 1976; MASSÉ & GUÉRIN, 1978; LUTZ *ET AL.*, 1982; BOOTH, 1983; ALCARAZ & DOMINGUEZ, 1985; WEEB, 1986, 1987; WOLOWICZ, 1987; FOOLER & LUTZ, 1989; GOODSELL *et al.*, 1992).

Water samples were taken to study the concentrations of chlorophyll *a* and phaeophityn *a* during the sampling period, following the fluorimetric technique (YENTSCH & MENZEL, 1963 *in* PISSARRA & CAVACO, 1984). Surface temperature and salinity were also recorded using a Kent Industrial Instruments model 5005 S-T meter.

Densities (ind./m^3) were estimated for each class of length (development stages) according to the size intervals expressed in Table 1 (LOOSANOFF *et al.*, 1966). Species were classified according to the criteria of ALCARAZ & DOMINGUEZ (1985): abundant species those that were present during large periods with high densities; regular species those with a large permanence in plankton community but low densities; and occasional species whose presence was occasionally recorded. Faunal gradients were determined following the method of BRYLINSKI (1986):

$$p_i = \left(\frac{N_i\,K_i}{\sum N_i\,K_i}\right) x100$$

This method allows to estimate for each species and at each station (according to the distance between two stations) an index where N_i is the abundance (ind./m^3) of the species at the station $_i$ and K_i a coefficient depending on the distance between two contiguous stations:

$$K_i = \left(\frac{d_i - d_{i-1}}{2}\right) + \left(\frac{d_{i+1} - d_i}{2}\right)$$

where d_i is the distance from station $_i$ to the origin (the mouth of the estuary). The curves obtained by this method allow to classify a species as characteristic of the upper estuary (convex curve) or from the mouth of estuary (concave curve), while a straight represents an intermediate species.

The ANOVA was used to test differences of the values of temperature, salinity and pigments among stations.

Results

Space-time distribution

Twenty seven species of bivalve larvae were identified during the sampling period (Table II). The higher densities of bivalve larvae were recorded during the months of May and July in stations 4 and 6 (6 to 10 Km from the mouth of the estuary). According to Fig. 2, the maximum density of larvae occurred in April/May and July, followed by an abrupt decrease in Autumn. This suggests two main reproductive periods in Spring and Summer, followed by a period of sexual pause during late Autumn and Winter. The higher concentration of bivalve larvae was recorded in the intermediate section of the estuary, between stations 4 and 7. The D larvae showed a very constant distribution during the sampling period, with two peaks, one in April and a secondary one in July/August (Fig.3).

Table II resumes the periods of occurrence of the 27 species identified, while Table III is relative to the abundance in each station during the sampling period.

Seven species were considered abundant: *Adula simpsoni*; *Mytilus edulis*, *Ostrea edulis*, *Loripes lacteus*, *Cerastoderma edule*, *Ensis siliqua* and *Thracia distorta*. *A. simpsoni* and *M. edulis* were present mainly in stations near the mouth of the estuary, with higher densities at high tide and a peak in August. *O. edulis* showed a tendency for presenting higher densities in the upper estuary during high tide, and is present in the water mass from May to September, with a moodier peak in July/August. *L. lacteus* and *Cerastoderma edule* both presenting a peak of abundance in April, were almost confined to the mouth of the estuary, reaching at maximum the limit of tidal excursion (7.5 Km ≈ St.4). *E. siliqua* and *T. distorta* both presented a wider distribution reaching station 7, with abundance peaks in March and April respectively.

Regular species were considered to be *Striarca lactea*, *Modiolus barbatus*, *Anomia ephippium*, *Crassostrea angulata*, *Venus verrucosa*, *Spisula solida*, *Barnea candida* and Pectinidae ni. All these species showed a distribution limited in its upper limit to station 4 (8 km far from the estuary), with the exception of *V. verrucosa*, confined to the mouth of estuary (St.1) and *C. angulata*, which presented a distribution similar to *O. edulis*, reaching St.8.

Occasional species were *Nucula nucleus*, *Divaricella divaricata*, *Lucinoma borealis*, *Kellia suborbicularis*, *Venerupis pullastra*, *Venerupis aurea*, *Venus striatula*, *Mactra corallina*, *Donax trunculus*, *Tellina fabula*, *Scrobicularia plana*, *Abra alba* and *Corbula gibba* (Table III). All these species are present in the zooplankton assemblage during at the most three months, mainly between April and July, and with higher densities in April. Their distribution is also similar, having their upper limit of occurrence in St.4, and mainly concentrated in St. 1 and 2. With the exception of *M. corallina* and *C. gibba*, all the other species of this group were only sampled during high tide.

Temperature, Salinity, Chlorophyll *a* and Phaeopigments

Chlorophyll *a* and phaeopigments increased towards upper estuary, with the higher values recorded during low tide periods. Two peaks of pigments were recorded, the first in April and the second in July, in agreement the maximum densities of bivalve larvae. In the study area lower temperatures (Table Va) were recorded during low tides in February (14°C), while maximum values were recorded in August, also during low tides (25.4°C). Salinity ranged from 25.6 ‰ (April) to 36‰ (August) during low tide, and 15‰ (April) to 29.1‰ (September) during high tide (Table Vb).

ANOVA test showed that there are significative differences between stations in what concerns salinity both between stations and months, while the temperature only recorded significative differences between stations. Also Chlorophyll *a* showed strong differences between stations and months.

Faunal Gradients

Considering the Mira estuary as a continous transect, and according to the curves of cumulative frequencies, Fig. 4 to Fig. 10 show that only three kinds of "geographical separation" can be proposed. *Cerastoderma edule* (CSP); *Ensis siliqua* (ESI); *Adula simpsoni* (ASI) and *Thracia distorta* (TDI) are considered as typically marine species. *Loripes lacteus* (LLA) and *Mytilus edulis* (MED) are considered with marine affinity. *Ostrea edulis* (OED) occurred mainly in the interior of the estuary, and was the only of these seven species that clearly could be considered as an estuarine species.

Discussion

The periods of residence in the plankton assemblage of *Mytilus edulis* (*e.g.* STAFFORD, 1912; NELSON, 1928; LEBOUR, 1938; SULLIVAN, 1948; SENTZ-BRACONNOT, 1968; CHANLEY & ANDREWS, 1971; ALCARAZ & DOMINGUEZ, 1985); *Nucula nucleus*, *Striarca lactea*, *Lucinoma borealis* e *Abra alba* (*e.g.* LEBOUR, 1938); *Anomia ephippium* (*e.g.* LEBOUR, 1938; SENTZ-BRACONNOT, 1968); *Corbula gibba* (*e.g.* LEBOUR, 1938); *Ostrea edulis* (*e.g.* SENTZ-BRACONNOT, 1968; KORRINGA, 1952; ALCARAZ & DOMINGUEZ, 1985; HIS *et al.*, 1989); *Loripes lacteus* (*e.g.* MASSÉ & GUÉRIN, 1978); *Venus verrucosa*, (*e.g.* MASSÉ & GUÉRIN, 1978; ALCARAZ & DOMINGUEZ, 1985); *Venerupis aurea*, *Venerupis pullastra* and *Cerastoderma edule*, (*e.g.* ALCARAZ & DOMINGUEZ, 1985) are similar to those found in the Mira estuary.

The highest densities of bivalve larvae recorded in the middle estuary (between Sts. 4 and 6), were also recorded for another Portuguese estuary, the Mondego estuary (GONÇALVES, 1991). This situation, according to those authors, could be attributed to the chemical stability of the water mass (only affected by tidal flux); to the retention in water masses of marine species, and the strong interespecific relationships in what concerns the energy fluxes.

In the upper estuary the diversity is lower, in relation with lower salinities. Nevertheless, in those stations and during the period from May to September, it was recorded the presence of large populations of the medusa *Blackfordia virginica*, a major planktonic predator, that can contribute to the variations of density in bivalve larvae (PAULA, 1987). The density of that species was so high, that sampling was not possible to carry out in the upper estuary (stations 9 and 10) from May to July.

Salinity showed to be a major barrier on larval dispersion; in fact two distinct groups arose: *A. simpsoni*, *L. lacteus*, and *T.distorta* occurring between 23 and 35‰; and *M. edulis*, *E.siliqua*, *C. edule* and *O.edulis*, ranging from 12 to 35‰; also the ANOVA results confirmed the differences between stations located at upper and lower estuary, namely in the period April/July. These results are identical to those obtained by the method of faunal gradient detection by BRYLINSKI (1986), where *E. siliqua*, *Cerastoderma edule* and *A. simpsoni* indicate a preference for marine salinities; *L. lacteus* and *M.edulis* a preference for higher salinities and only *Ostrea edulis* shows a clear affinity for lower salinities.

HIS *et al.* (1985), ALCARAZ & DOMINGUEZ (1985), MANN (1985) showed a positive relationship between larval distribution and chlorophyll *a* peaks, while SCROPE-HOWE & JONES, 1986 *in* MANN, 1991 recorded night deplacements of larvae towards maximum concentrations of chlorophyll *a*. In the Mira estuary, the results showed an almost perfect association, both in time and space, between maximum larval density and the higher values of chlorophyll *a* and phaeopigments.

The larval retention in the Mira estuary seems to be mainly associated with salinity. MANN (1991) stated that estuaries present both horizontal and vertical gradients of temperature and salinity, with significant differences of density between surface and bottom, thus originating a marine flux at the surface and a continental flux at the bottom. Under those conditions vertical migrations can contribute in an essential way to larval retention in an estuary. Also RÉ (1991) states that the distribution of both larvae and eggs of anchovy indicates larval retention in the Mira estuary.

In the case of the Mira estuary temperature didn't show to be determinant for larval distribution, as a matter of fact during the periods of maximum density of March/April, salinity is the main factor affecticing larval distribution, and the differences of salinity values between stations conditioned larval distribution. This result agrees with the conclusions of ALCARAZ & DOMINGUEZ (1985) who found no evidence of distribution of bivalve larvae as a function of temperature. Furthermore, ANDRADE (1986) showed that there is no significant differences between surface and bottom temperatures, and also found no evidence of species distribution as a function of temperature while studying macrobenthos.

The presence of the first larval stage, the D larvae, common to all the different bivalve species and occurring from some hours to few days after fecundation, was used to establish indirectly which were the main reproduction periods occur. April/May and July were the main peaks of abundance associated with reproduction events for all bivalve species recorded, but *A. simpsoni*, *L. lacteus*, *C.* sp. and *T. distorta* seemed to present a continuos reproduction, once the *veliconcha* stage was always present with high frequencies. On the other hand, the settlement time of bivalve larvae was based on the decrease of frequencies of the *pediveligera* class, which indicate as the most probable settling periods April, July and October for *A. simpsoni*; March and May for *L. lacteus*; April and August for *T. distorta*; March July and September for *M. edulis*; May, June and August for *E. siliqua* and May to August for *O. edulis*.

Conclusion

In the Mira estuary chlorophyll *a* concentrations were found to be probably the major factor favouring bivalve larvae abundance, while salinity was the factor controlling larval dispersion. Temperature only indirectly influenced dispersion and abundance, as a factor conditioning chlorophyll *a* abundance. Present results seem to clearly confirm the general statement that in southern European estuaries bivalves will have more than one reproductive period, with two larval peaks in April/May and July. Also the possibility of continuos reproduction of some species during large periods, was evidenced by the occurrence of larvae from March to October of *A. simpsoni*, *L. lacteus*, *C. edule* and *T. distorta*. As a matter of fact, the values of temperature between May and October, always superior to 20° C together with the values of Chlorophyll *a*, are probably the main factors infavouring continuos gonad output during Spring and Summer at this latitude. Thus, population dynamics of adult bivalve molluscs populations will be definitely conditioned by the presence of more than one yearly recruitment.

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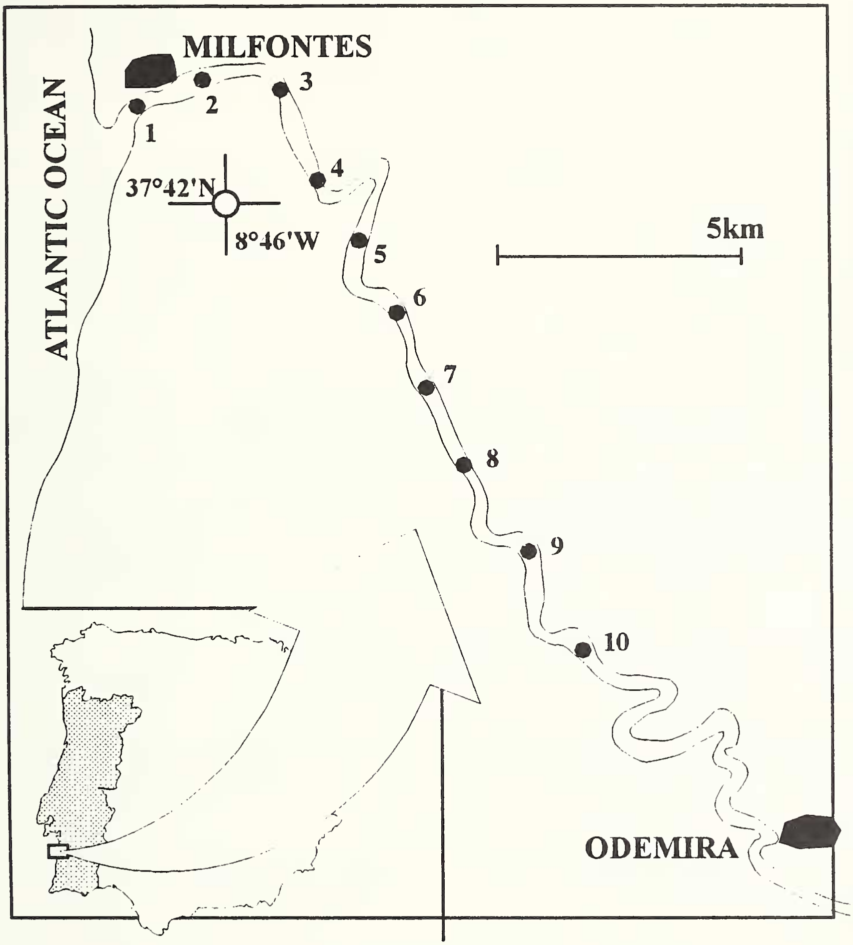

Fig.1 - Location of sampling points at the Mira estuary.

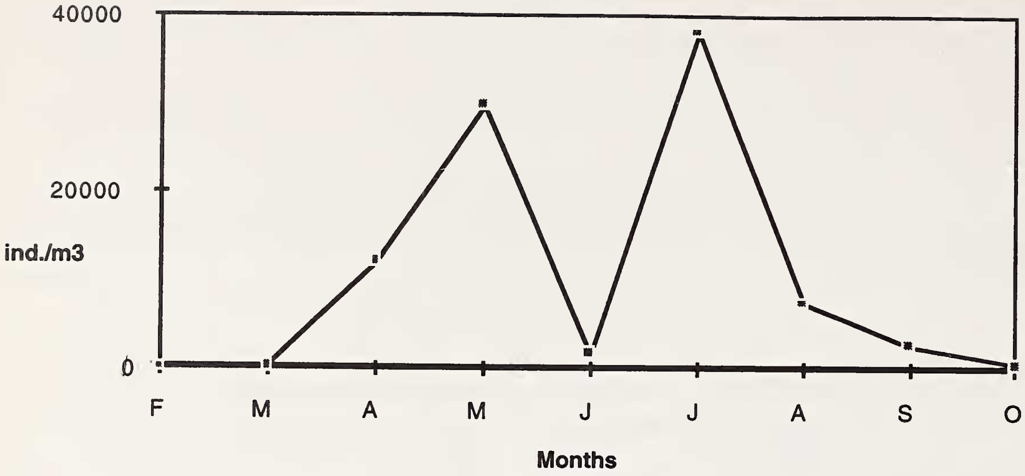

Fig. 2 - Total number of bivalve larvae (ind./m^3) during the sampling period in the Mira estuary.

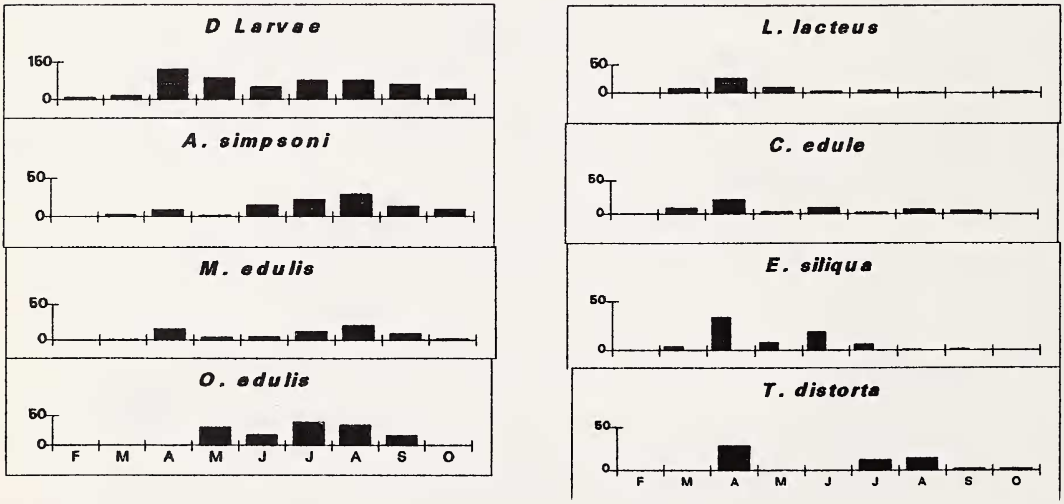

Fig. 3 - Monthly variation of the most abundant species of bivalve larvae (ind./m^3) in the Mira estuary during the sampling period.

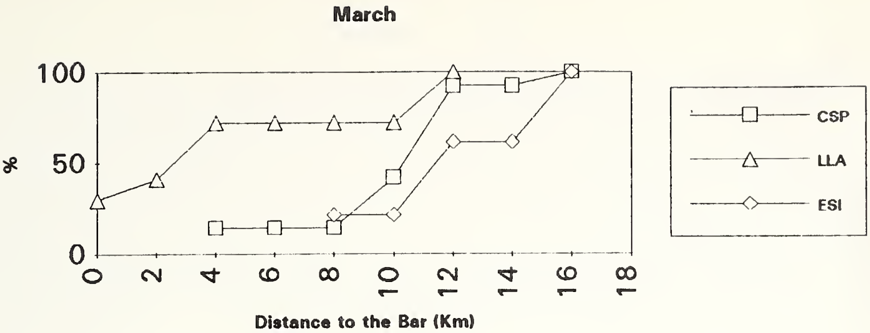

Fig. 4 - Curves of cumulative frequencies according to the Brylinski index of the most abundant bivalve larvae along the Mira estuary during March; CSP - *Cerastoderma edule*; LLA - *Loripes lacteus*; ESI - *Ensis siliqua*; ASI - *Adula simpsoni*; TDI - *Thracia distorta*; MED - *Mytilus edulis*; OED - *Ostrea edulis*.

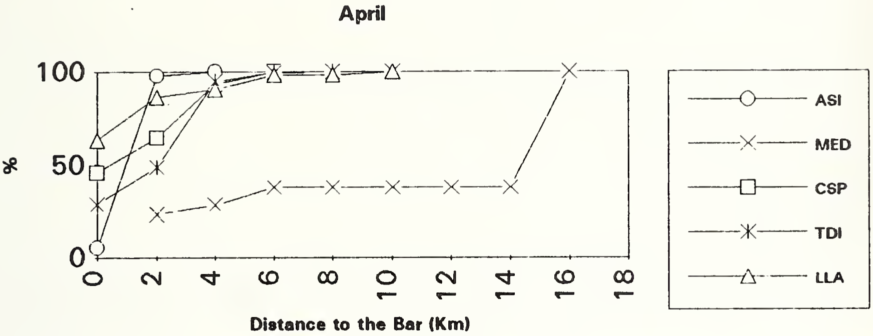

Fig. 5 - Curves of cumulative frequencies according to the Brylinski index of the most abundant bivalve larvae along the Mira estuary during April; CSP - *Cerastoderma edule*; LLA - *Loripes lacteus*; ESI - *Ensis siliqua*; ASI - *Adula simpsoni*; TDI - *Thracia distorta*; MED - *Mytilus edulis*; OED - *Ostrea edulis*.

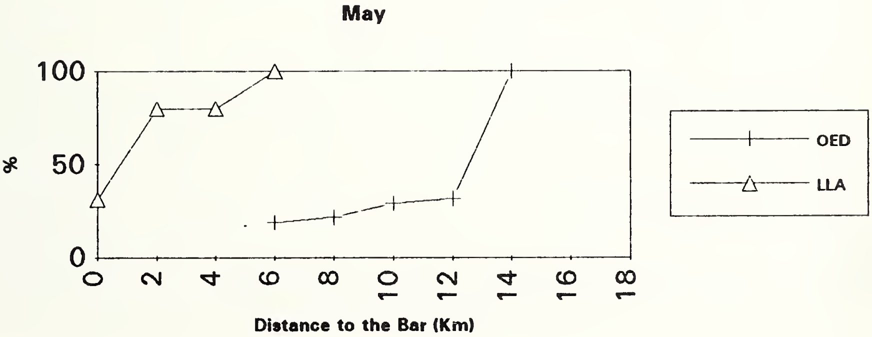

Fig. 6 - Curves of cumulative frequencies according to the Brylinski index of the most abundant bivalve larvae along the Mira estuary during May; CSP - *Cerastoderma edule*; LLA - *Loripes lacteus*; ESI - *Ensis siliqua*; ASI - *Adula simpsoni*; TDI - *Thracia distorta*; MED - *Mytilus edulis*; OED - *Ostrea edulis*.

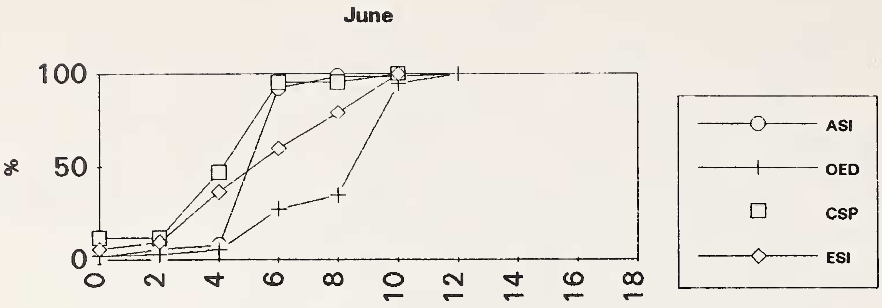

Fig. 7 - Curves of cumulative frequencies according to the Brylinski index of the most abundant bivalve larvae along the Mira estuary during June; CSP - *Cerastoderma edule*; LLA - *Loripes lacteus*; ESI - *Ensis siliqua*; ASI - *Adula simpsoni*; TDI - *Thracia distorta*; MED - *Mytilus edulis*; OED - *Ostrea edulis*.

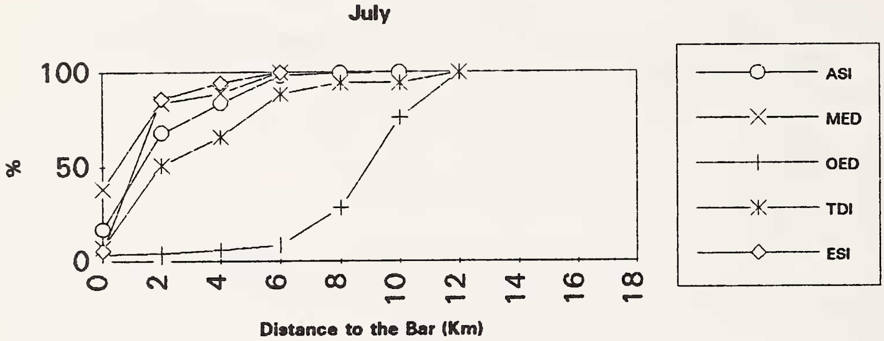

Fig. 8 - Curves of cumulative frequencies according to the Brylinski index of the most abundant bivalve larvae along the Mira estuary during July; CSP - *Cerastoderma edule*; LLA - *Loripes lacteus*; ESI - *Ensis siliqua*; ASI - *Adula simpsoni*; TDI - *Thracia distorta*; MED - *Mytilus edulis*; OED - *Ostrea edulis*.

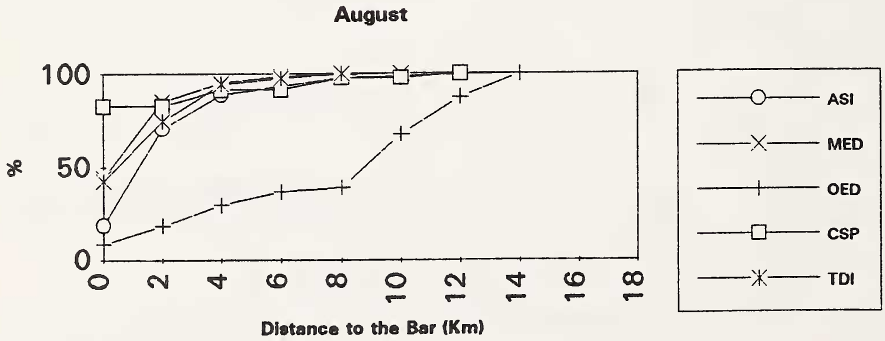

Fig. 9 - Curves of cumulative frequencies according to the Brylinski index of the most abundant bivalve larvae along the Mira estuary during August; CSP - *Cerastoderma edule*; LLA - *Loripes lacteus*; ESI - *Ensis siliqua*; ASI - *Adula simpsoni*; TDI - *Thracia distorta*; MED - *Mytilus edulis*; OED - *Ostrea edulis*.

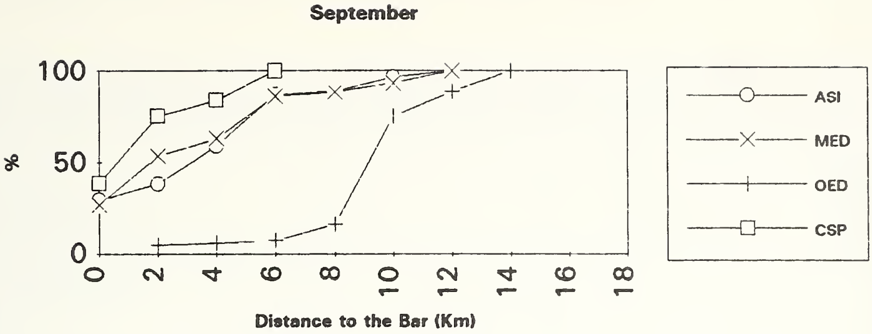

Fig. 10 - Curves of cumulative frequencies according to the Brylinski index of the most abundant bivalve larvae along the Mira estuary during September; CSP - *Cerastoderma edule*; LLA - *Loripes lacteus*; ESI - *Ensis siliqua*; ASI - *Adula simpsoni*; TDI - *Thracia distorta*; MED - *Mytilus edulis*; OED - *Ostrea edulis*.

Table I - Minimum length (mm) for development stages, D larvae, *veliconcha* and *pediveligera* for the most abundant species.

Species	D Larvae	Veliconcha	Pediveligera
Adula simpsoni	100	150	300
Mytilus edulis	90	150	300
Ostrea edulis		130	200
Loripes lacteus	78	200	325
Cerastoderma edule	140	160	300
Ensis siliqua	80	140	280
Thracia distorta	89	200	350

Table II - Periods of occurrence of the bivalve larvae recorded at the Mira estuary.

	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
Nucula nucleus			•••••••••		•••••••••	•••••••••			
Striarca lactea		•••••••••		•••••••••	•••••••••		•••••••••	•••••••••	•••••••••
Adula simpsoni	•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	•••••••••
Mytilus edulis		•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	•••••••••
Modiolus barbatus		•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	
Pectinidae		•••••••••	•••••••••	•••••••••	•••••••••	•••••••••			•••••••••
Anomia ephippium		•••••••••	•••••••••	•••••••••		•••••••••	•••••••••	•••••••••	
Ostrea edulis				•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	
Crassostrea angulata				•••••••••	•••••••••		•••••••••	•••••••••	
Divaricela divaricata		•••••••••		•••••••••	•••••••••				
Lucinoma borealis		•••••••••		•••••••••	•••••••••				
Loripes lacteus		•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	•••••••••		•••••••••
Kellia suborbicularis			•••••••••						
Cerastoderma edule		•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	
Venerupis pullastra			•••••••••	•••••••••		•••••••••			
Venerupis aurea			•••••••••	•••••••••					
Venus verrucosa		•••••••••	•••••••••	•••••••••		•••••••••			•••••••••
Venus striatula			•••••••••						•••••••••
Mactra corallina		•••••••••	•••••••••						
Spisula solida			•••••••••	•••••••••			•••••••••	•••••••••	
Donax trunculus			•••••••••				•••••••••		
Tellina fabula			•••••••••						
Scrobicularia plana			•••••••••	•••••••••					
Abra alba								•••••••••	
Ensis siliqua		•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	•••••••••	
Corbula gibba			•••••••••		•••••••••				
Barnea candida		•••••••••	•••••••••	•••••••••	•••••••••		•••••••••	•••••••••	•••••••••
Thracia distorta			•••••••••			•••••••••	•••••••••	•••••••••	•••••••••

Table III - Classification of the bivalve larvae in the Mira estuary, according to the criteria of Alcaraz & Dominguez (1985).

Species	Abundant	Regular	Occasional
Nucula nucleus			X
Striarca lactea		X	
Adula simpsoni	X		
Mytilus edulis	X		
Modiolus barbatus		X	
Pectinidae			X
Anomia ephippium		X	
Ostrea edulis	X		
Crassostrea angulata		X	
Divaricela divaricata			X
Lucinoma borealis			X
Loripes lacteus	X		
Kellia suborbicularis			X
Cerastoderma edule	X		
Venerupis pullastra			X
Venerupis aurea			X
Venus verrucosa		X	
Venus striatula			X
Mactra corallina			X
Spisula solida		X	
Donax trunculus			X
Tellina fabula			X
Scrobicularia plana			X
Abra alba			X
Ensis siliqua	X		
Corbula gibba			X
Barnea candida		X	
Thracia distorta	X		

Table IV - Monthly variation of Chlorophyll a and Phaeopigments and ANOVA results between stations in the Mira estuary at low tide (lw) and high tide (hw).

		HW		LW				HW			LW
Sta.	Mon.	Clor.	Pheo.	Clor.	Pheo.	Sta.	Mon.	Clor.	Pheo.	Clor.	Pheo.
1	F	0,1	0,1			6	F				
	M	0,2	0,1	0,4	0,4		M	0,5	1	0,7	1
	A	1	0,5	1,4	0,5		A	0,9	0,6	1,2	0,7
	A	0,2	0,3	0,1	0,3		A	0,4	0,4	0,5	0,7
	A	0,7	0,9	0,5	0,5		A	1,4	1,1	1,7	0,9
	A	0,2	0,2	1,1	0,6		A	3,3	1,2	2,3	1,2
	M	0,3	0,2	1	1,8		M	1,5	1,1	8,6	2,2
	J	0,8	0,5	0,9	0,7		J	1,5	1,1	2,9	1,3
	J	0,8	0,3	1,4	0,7		J			8	3,4
	A	0,7	0,3	0,5	0,3		A	2,3	0,9	1,6	1
	S	0,6	0,8	0,5	0,3		S	0,8	0,4	1,1	0,5
	O	0,4	0,3	0,3	0,3		O	0,3	0,4	1,1	0,6
2	F					7	F				
	M	0,1	0,2	0,8	0,4		M	1,2	0,1	0,5	0,4
	A	0,5	3	0,3	0,2		A	2,6	0,6	1,8	0,7
	A	0,2	0,3	0,1	0,3		A	0,6	0,4	1,7	0,9
	A	0,5	0,5	1,1	0,5		A	1,5	0,9	2,2	0,8
	A	0,4	0,3	2,3	1,1		A	2,6	1,4	1,8	0,9
	M	0,3	0,2	2,2	1,1		M	2	1,4	9,5	1,8
	J	0,8	0,4	1,2	0,8		J	1,9	1,4	2,5	1,6
	J	0,7	0,4	2	1		J	3,1	1,8	11	3,7
	A	0,7	0,5	1,2	0,5		A	2,6	1	1,6	1,2
	S	0,5	0,8	0,6	0,2		S	0,7	0,4	1,5	0,7
	O	0,4	0,4	0,1	0,2		O	0,3	0,4	0,8	0,5
3	F	0,3	0,3	0,6	0,4	8	F	0,2	0,2	0,2	0,2
	M	0,1	0,1	0,9	0,6		M	0,5	0,6	0,3	0,4
	A	0,5	0,3	0,4	0,2		A	5,3	1,7	3,2	1,1
	A	0,2	0,3	0,2	0,3		A	0,4	0,5	0,6	0,7
	A	0,5	0,5	1,4	0,5		A	2,3	0,9	3,1	1,5
	A	0,4	0,3	2,5	1,3		A	3	1,3	3,9	1,8
	M	0,3	0,2	3,4	1,5		M	2,4	1,5	9	3
	J	0,8	0,4	1,3	0,8		J				
	J	0,7	0,4	3,7	1,8		J				
	A	0,7	0,5	1,6	0,6		A	0,8	0,2	2,1	1,6
	S	0,5	0,8	0,7	0,2		S	1,5	0,6	2	0,2
	O	0,4	0,4	0,2	0,3		O	0,4	0,5	0,2	0,3
	F						F				

cont'd

Table IV - cont'd.

		HW		LW				HW			LW
Sta.	Mon.	Clor.	Pheo.	Clor.	Pheo.	Sta.	Mon.	Clor.	Pheo.	Clor.	Pheo.
4	M	0,4	0,9	0,6	0,5	9	M	0,7	0,6	0,4	0,4
	A	0,7	0,3	0,3	0,3		A	2,3	1,3	6,9	2
	A	0,2	0,3	0,3	0,4		A	0,6	0,7		
	A	0,6	0,6	2	0,7		A	1,2	1		
	A	0,8	0,7	2,3	1,3		A				
	M	0,5	0,5	3,4	1,4		M				
	J	1,4	0,9	1,4	0,8		J				
	J	0,9	0,6	6	0,9		J				
	A	0,8	0,3	1,9	0,6		A				
	S	0,5	0,5	0,9	0,2		S				
	O	0,3	0,3	2,6	1,5		O				
5	F					10	F	0,3	0,4		
	M	0,4	0,4	0,9	0,7		M	0,6	0,9	0,8	0,9
	A	0,6	0,4	0,9	0,4		A	3,7	2	11	4,3
	A	0,6	0,3	0,4	0,5		A	1,5	1,3		
	A	1,1	0,7	1,8	0,7		A	4	2		
	A	3,4	1,2	2,8	1,7		A				
	M	1,1	0,9	3,6	1,7		M				
	J	1,4	1	1,7	0,8		J				
	J	2,4	1,3	4,8	2,2		J				
	A	1,4	0,6	1,8	0,8		A				
	S	0,7	0,3	0,9	0,4		S				
	O	1,6	0,7	0,7	0,6		O				

Clor	D F	Sigma	F Test
Stations - HW	9	0	***
Months	11	0	***
Stations - LW	9	0,04	*
Months	11	4.88E-06	***

Pheo	D F	Sigma	F Test
Stations - HW	9	0,21	not significant
Months	11	0	**
Stations - LW	9	0,02	*
Months	11	5.09E-05	***

Table Va - Monthly variation of temperature and ANOVA results between stations in each station at high tide (hw) and low tide (lw).

	Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct	
St.	hw	lw	hw	lw	hw	lw	hw	lw	hw	lw	hw	lw	hw	lw	hw	lw	hw	lw
1	16	14,6	14,6	14	15	15	17	18	17	19	18	22	19	21	18	19	21	22
2	16	14,8	14,4	14	15	16	17	19	17	20	18	24	19	23	18	20	21	20
3	16	14,6	14,4	15	15	17	17	21	17	21	19	25	19	25	18	21	20	20
4	16	14,5	19,8	15	15	17	17	22	19	22	22	26	20	26	19	22	20	20
5	15	14,4	15,5	15	17	18	20	22	21	23	24	26	23	27	22	23	20	20
6	15	14,1	16	15	17	18	22	23	22	24	25	27	25	27	22	24	20	20
7	15	13,8	16	15	18	18	22	23	23	24	25	27	26	27	22	24	20	20
8	14	13,8	16	15	18	18	23	23					26	28	23	24	20	19
9	14	13,4	16	16	18													
10	14	13,2	16	16	18													

	DF	Sigma	Ftest
Stations-HW	9	8,95E-10	***
Months	8	0,887	notsignificant
Stations-LW	9	4,87E-14	***
Months	8	0,175	not significant

Table Vb - Monthly variation of salinity and ANOVA results between stations in each station at high tide (hw) and low tide (lw).

	Feb		Mar		Apr		May		Jun		Jul		Ago		Sep		Oct	
St.	hw	lw	hw	lw	hw	lw	hw	lw	hw	lw	hw	lw	hw	lw	hw	lw	hw	lw
1	35	38	36	32	35	34	35	35	35	34	35	36	40	37	40	40	38	36
2	35	35	36	29	35	27	35	30	35	33	36	36	40	35	39	37	38	32
3	35	30	36	26	35	23	35	26	35	29	36	24	40	34	38	35	31	29
4	31	28	27	25	35	17	35	20	33	28	35	30	39	30	38	31	30	25
5	26	24	32	21	30	10	32	19	28	22	32	24	37	26	35	25	24	19
6	22	20	29	16	28	6	27	14	25	18	29	20	35	22	32	24	20	17
7	17	17	24	16	23	3	27	10	23	15	26	18	32	23	30	21	19	14
8	16	15	21	14	18	0	24						31	20	28	20	15	11
9	12	11	16	10	12													
10	6	6	11	7	5													

	DF	Sigma	FTest
Stations-HW	9	8,40E-32	***
Months	8	0,001	**
Stations-LW	9	2,19E-37	***
Months	8	1,60E-09	***

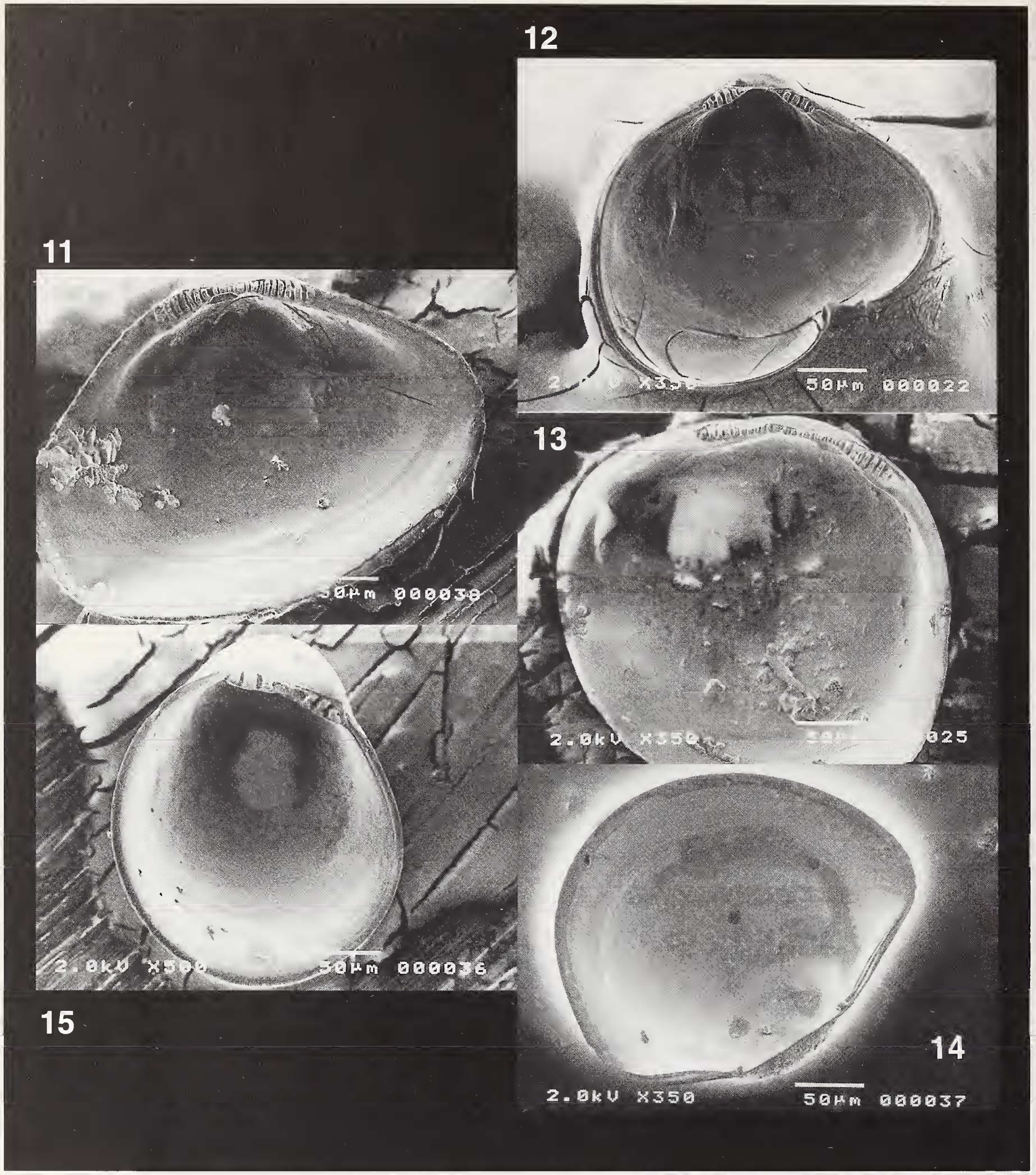

Fig. 11. Left shell of *Adula simpsoni*; Fig. 12. Right shell of *Anomia ephippium*; Fig. 13. Right shell of *Mytilus edulis*; Fig. 14. Right shell of *Ensis siliqua*; Fig. 155. Left shell of *Crassostrea angulata*.